

Annex P

Sources of Greenhouse Gas Emissions Excluded

Although this report is intended to be a comprehensive assessment of anthropogenic¹ sources and sinks of greenhouse gas emissions for the United States, certain sources have been identified yet excluded from the estimates presented for various reasons. Before discussing these sources, however, it is important to note that processes or activities that are not *anthropogenic in origin* or do not result in a *net source or sink* of greenhouse gas emissions are intentionally excluded from a national inventory of anthropogenic greenhouse gas emissions. In general, processes or activities that are not anthropogenic are considered natural (i.e., not directly influenced by human activity) in origin and, as an example, would include the following:

- o Volcanic eruptions
- o CO₂ exchange (i.e., uptake or release) by oceans
- o Natural forest fires²
- o CH₄ emissions from wetlands not affected by human induced land-use changes

Some processes or activities may be anthropogenic in origin but do not result in net emissions of greenhouse gases, such as the respiration of CO₂ by people or domesticated animals. Given a source category that is both anthropogenic and results in net greenhouse gas emissions, reasons for excluding a source related to an anthropogenic activity include one or more of the following:

- o There is insufficient scientific understanding to develop a reliable method for estimating emissions at a national level.
- o Although an estimating method has been developed, data were not adequately available to calculate emissions.
- o Emissions were implicitly accounted for within another source category (e.g., CO₂ from Fossil Fuel Combustion).

It is also important to note that the United States believes the exclusion of the sources discussed below introduces only a minor bias in its overall estimate of U.S. greenhouse gas emissions.

Separate Cruise and LTO Emissions from the Combustion of Jet Fuel

The combustion of jet fuel by aircraft results in emissions of CH₄, N₂O, CO, NO_x, and NMVOCs. The emissions per mass of fuel combusted during landing/take-off (LTO) operations differ from those during aircraft cruising. Accurate estimation of these emissions requires a detailed accounting of LTO cycles and fuel consumption during cruising by aircraft model (e.g., Boeing 747-400). Sufficient data for separately calculating near ground-level emissions during landing and take-off and cruise altitude emissions by aircraft model were not available for this report. (see *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual*, pp. 1.93 - 1.96)

¹ The term "anthropogenic", in this context, refers to greenhouse gas emissions and removals that are a direct result of human activities or are the result of natural processes that have been affected by human activities (IPCC/UNEP/OECD/IEA 1997).

² In some cases forest fires that are started either intentionally or unintentionally are viewed as mimicking natural burning processes which have been suppressed by other human forest management activities. The United States does not consider forest fires within its national boundaries to be a net source of greenhouse emissions.

CO₂ from Burning in Coal Deposits and Waste Piles

Coal is periodically burned in deposits and waste piles. It has been estimated that the burning of coal in deposits and waste piles would represent less than 1.3 percent of total U.S. coal consumption, averaged over ten-years. Because there is currently no known source of data on the quantity of coal burned in waste piles and there is uncertainty as to the fraction of coal oxidized during such burnings, these CO₂ emissions are not currently estimated. Further research would be required to develop accurate emission factors and activity data for these emissions to be estimated (see *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual*, p. 1.112 - 1.113).

Fossil CO₂ from Petroleum and Natural Gas Wells, CO₂ Separated from Natural Gas, and CO₂ from Enhanced Oil Recovery (EOR)

Petroleum and natural gas well drilling, petroleum and natural gas production, and natural gas processing -- including removal of CO₂ -- may result in emissions of CO₂ that was at one time stored in underground formations.

Carbon dioxide and other gases are naturally present in raw natural gas, in proportions that vary depending on the geochemical circumstances that caused the formation of the gas. After the heavier gases are removed during processing, small amounts of carbon dioxide may be allowed to remain in the natural gas. If the amount of CO₂ sufficiently lowers the heating value of the natural gas, it is typically extracted by amine scrubbing and, in most cases, released into the atmosphere. These emissions can be estimated by calculating the difference between the average carbon dioxide content of raw natural gas and the carbon dioxide content of pipeline gas. The Energy Information Administration (EIA) estimates that annual CO₂ emissions from scrubbing are about 4 million metric tons of carbon. Because of imprecision in the reporting of U.S. natural gas production and processing, emissions estimates from energy production sources may be double-counted or under-reported, and thus are uncertain.

Carbon dioxide is also injected into underground deposits to increase crude oil reservoir pressure in a field technique known as enhanced oil recovery (EOR). It is thought that much of the injected CO₂ may be effectively and permanently sequestered, but the fraction of injected CO₂ that is re-released remains uncertain. The fraction re-released varies from well to well depending upon the field geology and the gas capture/re-injection technology employed at the wellhead. Over time, carbon dioxide may also seep into the producing well and mix with the oil and natural gas present there. If the gas portion of this mixture has a sufficiently high energy content, it may be collected and sent to a natural gas plant; if not, it may be vented or flared. The EIA estimates that the amount of CO₂ used for EOR is on the order of 12 million metric tons, of which emissions would be some fraction yet to be defined. This figure is based on the difference between U.S. Department of Commerce sales figures for industrial CO₂ (17 million metric tons) minus the 5 million metric tons reported by the Freedonia Group that is used for purposes other than EOR. Further research into EOR is required before the resulting CO₂ emissions can be adequately quantified. (See Carbon Dioxide Consumption in the Industrial Processes chapter).

Carbon Sequestration in Underground Injection Wells

Organic hazardous wastes are injected into underground wells. Depending on the source of these organic substances (e.g., derived from fossil fuels) the carbon in them may or may not be included in U.S. CO₂ emission estimates. Sequestration of carbon containing substances in underground injection wells may be an unidentified sink. Further research is required if this potential sink is to be quantified.

CH₄ from Abandoned Coal Mines

Abandoned coal mines are a source of CH₄ emissions. In general, many of the same factors that affect emissions from operating coal mines will affect emissions from abandoned mines such as the permeability and gassiness of the coal, the mine's depth, geologic characteristics, and whether it has been flooded. A few gas developers have recovered methane from abandoned mine workings; therefore, emissions from this source may be significant. Further research and methodological development is needed if these emissions are to be estimated.

CO₂ from "Unaccounted for" Natural Gas

There is a discrepancy between the amount of natural gas sold by producers and that reported as purchased by consumers. This discrepancy, known as "unaccounted for" or unmetered natural gas, was assumed to be the sum of leakage, measurement errors, data collection problems, undetected non-reporting, undetected over reporting, and undetected under reporting. Historically, the amount of gas sold by producers has always exceeded that reportedly purchased by consumers; therefore, some portion of unaccounted for natural gas was assumed to be a source of CO₂ emissions. In other words, it was assumed that consumers were underreporting their usage of natural gas. In DOE/EIA's energy statistics for 1996, however, reported consumption of natural gas exceeded the amount sold by producers. Therefore, the historical explanation given for this discrepancy has lost credibility and unaccounted for natural gas is no longer used to calculate CO₂ emissions.

CO₂ from Shale Oil Production

Oil shale is shale saturated with kerogen.³ It can be thought of as the geological predecessor to crude oil. Carbon dioxide is released as a by-product of the process of producing petroleum products from shale oil. As of now, it is not cost-effective to mine and process shale oil into usable petroleum products. The only identified large-scale oil shale processing facility in the United States was operated by Unocal during the years 1985 to 1990. There have been no known emissions from shale oil processing in the United States since 1990 when the Unocal facility closed.

CH₄ from the Production of Carbides other than Silicon Carbide

Methane (CH₄) may be emitted from the production of carbides because the petroleum coke used in the process contains volatile organic compounds, which form CH₄ during thermal decomposition. Methane emissions from the production of silicon carbide were estimated and accounted for, but emissions from the production of calcium carbide and other carbides were not. Further research is needed to estimate CH₄ emissions from the production of calcium carbide and other carbides other than silicon carbide. (See *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual*, pp. 2.20 - 2.21)

CO₂ from Calcium Carbide and Silicon Carbide Production

Carbon dioxide is formed by the oxidation of petroleum coke in the production of both calcium carbide and silicon carbide. These CO₂ emissions are implicitly accounted for with emissions from the combustion of petroleum coke in the Energy chapter. There is currently not sufficient data on coke consumption to estimate emissions from these sources explicitly. (See *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual*, pp. 2.20 - 2.21)

CO₂ from Graphite Consumption in Ferroalloy and Steel Production

The CO₂ emissions from the three reducing agents used in ferroalloy and steel production -- coke, wood (or biomass), and graphite -- are accounted for as follows:

- o Emissions resulting from the use of coke are accounted for in the Energy chapter under Fossil Fuel Combustion.
- o Estimating emissions from the use of wood or other biomass materials is unnecessary because these emissions should be accounted for in Land-Use Change and Forestry chapter if the biomass is harvested on an unsustainable basis.

³ Kerogen is fossilized insoluble organic material found in sedimentary rocks, usually shales, which can be converted to petroleum products by distillation.

- o The CO₂ emissions from the use of graphite, which is produced from petroleum by-products, may be accounted for in the Energy chapter, although further analysis is required to determine if these emissions are being properly estimated. The CO₂ emissions from the use of natural graphite, however, have not been accounted for in the estimate.

Emissions from graphite electrode consumption -- versus its use as a reducing agent -- in ferroalloy and steel production may at present only be accounted for in part under fossil fuel combustion if the graphite used was derived from a fossil fuel substrate, versus natural graphite ore. Further research into the source and total consumption of graphite for these purposes is required to explicitly estimate emissions. (See Iron and Steel Production and Ferroalloy Production in the Industrial Processes chapter)

N₂O from Caprolactam Production

Caprolactam is a widely used chemical intermediate, primarily to produce nylon-6. All processes for producing caprolactam involve the catalytic oxidation of ammonia, with N₂O being produced as a by-product. Caprolactam production could be a significant source of N₂O -- it has been identified as such in the Netherlands. More research is required to determine this source's significance because there is currently insufficient information available on caprolactam production to estimate emissions in the United States. (See *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual*, pp. 2.22 - 2.23)

N₂O from Cracking of Certain Oil Fractions

In order to improve the gasoline yield in crude oil refining, certain oil fractions are processed in a catcracker. Because crude oil contains some nitrogen, N₂O emissions may result from this cracking process. There is currently insufficient data to develop a methodology for estimating these emissions. (See *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual*, p. 2.23)

CH₄ from Coke Production

Coke production may result in CH₄ emissions. Detailed coke production statistics were not available for the purposes of estimating CH₄ emissions from this minor source. (See Petrochemical Production in the Industrial Processes chapter and the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual*, p. 2.23)

CO₂ from Metal Production

Coke is used as a reducing agent in the production of some metals from their ores, including magnesium, chromium, lead, nickel, silicon, tin, titanium, and zinc. Carbon dioxide may be emitted during the metal's production from the oxidization of this coke and, in some cases, from the carbonate ores themselves (e.g., some magnesium ores contain carbonate). The CO₂ emissions from coke oxidation are accounted for in the Energy chapter under Fossil Fuel Combustion. The CO₂ emissions from the carbonate ores are not presently accounted for, but their quantities are thought to be minor. (See *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual*, p. 2.37 - 2.38)

N₂O from Acrylonitrile Production

Nitrous oxide may be emitted during acrylonitrile production. No methodology was available for estimating these emissions, and therefore further research is needed if these emissions are to be included. (see *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual*, p. 2.22)

SF₆ from Aluminum Fluxing and Degassing

Occasionally, sulfur hexafluoride (SF₆) is used by the aluminum industry as a fluxing and degassing agent in experimental and specialized casting operations. In these cases it is normally mixed with argon, nitrogen, and/or chlorine and blown through molten aluminum; however, this practice is not used by primary aluminum production firms in the United States and is not believed to be extensively used by secondary casting firms. Where it does occur, the concentration of SF₆ in the mixture is small and a portion of the SF₆ is decomposed in the process (Waite and Bernard 1990, Corns 1990). It has been estimated that 230 Mg of SF₆ were used by the aluminum industry in the United States and Canada (Maiss and Brenninkmeijer 1998); however, this estimate is highly uncertain.

Miscellaneous SF₆ Uses

Sulfur hexafluoride may be used in gas-filled athletic shoes, in foam insulation, for dry etching, in laser systems, as an atmospheric tracer gas, for indoor air quality testing, for laboratory hood testing, for chromatography, in tandem accelerators, in sound-insulating windows, in tennis balls, in loudspeakers, in shock absorbers, and for certain biomedical applications. Data need to be gathered and methodologies developed if these emissions are to be estimated. A preliminary global assessment of aggregate emissions from these applications can be found in Maiss, M. and C.A.M. Brenninkmeijer (1998).

CO₂ from Solvent Incineration

CO₂ may be released during the incineration of solvents. Although emissions from this source are believed to be minor, data need to be gathered and methodologies developed if these emissions are to be estimated.

CO₂ from Non-Forest Soils

Non-forest soils emit CO₂ from decaying organic matter and carbonate minerals -- the latter may be naturally present or mined and later applied to soils as a means to adjust their acidity. Soil conditions, climate, and land-use practices interact to affect the CO₂ emission rates from non-forest soils. The U.S. Forest Service has developed a model to estimate CO₂ emissions from forest soils; a similar model is currently being developed for non-forest soils. A new methodology has been implemented in order to estimate CO₂ fluxes from non-forest soils in the 1990 to 1992 period, but more recent data that would permit the inclusion of 1993 to 1998 estimates in this Inventory had not yet been released (see Changes in Non-Forest Carbon Stocks in the Land-Use Change and Forestry chapter).

N₂O from Domestic House Animal Waste Deposited on Soils

A substantial amount of liquid and solid waste is produced by domestic animals that are kept as pets. A preliminary methodology was developed to estimate nitrous oxide (N₂O) emissions from the deposition of domestic house animal (i.e., dogs and cats) waste on lawns, fields and parks. Estimates calculated with this methodology suggest that, in 1990, approximately 330 thousand metric tons of nitrogen originating as domestic house animal waste were deposited on soils resulting in approximately 0.8 MMTCE of N₂O emissions from soils. To estimate the amount of nitrogen deposited by domestic house animals, only those excretions that remained on land surfaces -- as opposed to wastes that were collected by owners and are managed as municipal solid waste -- were included. Annual dog and cat population numbers were obtained from the Pet Food Institute.⁴ Annual nitrogen excretion rates were estimated from protein intake. The recommended protein intake for an average size adult of each animal type⁵ was multiplied by the average amount of nitrogen per unit of protein (0.16 kg N/kg protein, from the *Revised 1996 IPCC Guidelines*) to estimate nitrogen consumption. It was then assumed that 95 percent of this nitrogen was excreted, either in solid or liquid form (i.e., it was assumed that 5 percent was retained for fur and milk production). Of the total nitrogen

⁴ Pet Food Institute (1999) *Pet Incidence Trend Report*. Pet Food Institute, Washington DC.

⁵ Bright, S. (1999) Personal communication between Marco Alcaraz of ICF Consulting and Susan Bright of the Dupont Animal Clinic, Washington, D.C., August 1999.

excretion, 90 percent was assumed to occur through liquid waste, with the balance from solid waste.⁶ Both cat and dog populations were divided into urban and rural fractions, using the metropolitan and non-metropolitan human population categories, respectively, of the U.S. Census Bureau.⁷ Both liquid and solid wastes from the urban cat population, and solid waste from the urban dog population were assumed to be collected (i.e., not deposited on soils). Nitrous oxide emission estimates from domestic house animal excretion were calculated in the same manner as performed for estimating emissions from livestock excretion. Producing these estimates involved making a number of simplifying assumptions regarding average animal size and protein consumption, as well as the proportions of animal populations residing in urban and rural areas and the proportions of wastes that are deposited on land. Further methodological development and data collection is required in order to reduce the uncertainty involved in the domestic house animal excretion estimates.

CO₂ from Food Scraps Disposed in Landfills

A certain amount of food scraps generated from food processing or as leftovers join the waste stream and are landfilled. Nationally, an estimated 0.1 MMTCE per year are stored in the form of organic carbon contained in food scraps in landfills, acting as a carbon sink. A portion of the landfilled food scraps becomes a source of methane emissions, which offset the sink estimates to an extent. Further data collection on the amount and composition of food scraps generated and landfilled is required in order to reduce the uncertainty associated with this estimate.

CH₄ from Land-Use Changes Including Wetlands Creation or Destruction

Wetlands are a known source of methane (CH₄) emissions. When wetlands are destroyed, CH₄ emissions may be reduced. Conversely, when wetlands are created (e.g., during the construction of hydroelectric plants), CH₄ emissions may increase. Grasslands and forest lands may also be weak sinks for CH₄ due to the presence of methanotrophic bacteria that use CH₄ as an energy source (i.e., they oxidize CH₄ to CO₂). Currently, an adequate scientific basis for estimating these emissions and sinks does not exist, and therefore further research and methodological development is required.

CH₄ from Septic Tanks and Drainfields

Methane (CH₄) is produced during the biodegradation of organics in septic tanks if other suitable electron-acceptors (i.e., oxygen, nitrate, or sulfate) besides CO₂ are unavailable. Such conditions are called methanogenic. There were insufficient data and methodological developments available to estimate emissions from this source.

N₂O from Wastewater Treatment

As a result of nitrification and denitrification processes, nitrous oxide (N₂O) may be produced and emitted from both domestic and industrial wastewater treatment plants. Nitrogen-containing compounds are found in wastewater due to the presence of both human excrement and other nitrogen-containing constituents (e.g. garbage, industrial wastes, dead animals, etc.). The portion of emitted N₂O which originates from human excrement is currently estimated under the Human Sewage source category -- based upon average dietary assumptions. The portion of emitted N₂O which originates from other nitrogen-containing constituents is not currently estimated. Further research and methodological development is needed if these emissions are to be accurately estimated.

CH₄ from Industrial Wastewater Treatment

Methane (CH₄) may be produced during the biodegradation of organics in wastewater if other suitable electron-acceptors (i.e. oxygen, nitrate, or sulfate) besides CO₂ are unavailable. Such conditions are called methanogenic.

⁶ Swenson, M.J. and W.G. Reece, eds. (1993) *Duke's Physiology of Domestic Animals*. Cornell University Press. 11th Edition.

⁷ U.S. Census Bureau (1999) <<http://www.census.gov/population/estimates/metro-city/ma96-08.txt>>

Methane produced from domestic wastewater treatment plants is accounted for in the Waste chapter. These emissions are estimated by assuming an average 5-day biological oxygen demand (BOD_5) per capita contribution in conjunction with the approximation that 15 percent of wastewater's BOD_5 is removed under methanogenic conditions. This method itself needs refinement. It is not clear if industrial wastewater sent to domestic wastewater treatment plants, which may contain biodegradable material, are accounted for in the average BOD_5 per capita method when this wastewater is sent to domestic wastewater treatment plants. Additionally, CH_4 emissions from methanogenic processes at industrial wastewater treatment plants are not currently estimated. Further research and methodological development is needed if these emissions are to be accurately estimated. (See Wastewater Treatment in the Waste chapter)